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GLAUCOMA

Global rates of glaucoma surgery

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Abstract
Purpose To estimate global rates of glaucoma surgery.
Methods National glaucoma and national ophthalmology societies were contacted to obtain rates of glaucoma surgery for the preceding 5 years. In countries without a professional society, leading ophthalmologists or non-governmental organizations (NGO) were approached. When available, published literature was used for the estimates. Three levels of evidence were assigned: published data from central government or insurance registries (level I), estimates provided by a national professional society based on survey of members (level II), and estimates based on data from individual glaucoma surgeons (level III). Glaucoma surgical rate (GSR) was defined as the annual number of total glaucoma surgeries performed per million population. Linear regression analysis was performed between GSR and the following parameters: population per ophthalmologist, per capita gross domestic product (GDP), and per capita health expenditures.
Results Seventy-three glaucoma societies, 35 ophthalmology societies, as well as six NGOs and 37 leading ophthalmologists (11 other countries) were contacted. Data were obtained from 38 countries (10 level I, 23 level II, and 5 lev el III) with a total population of 1.723 billion. The average GSR was 139.2 ±113.1 (range, 2.9–500.0). There was a positive correlation between GSR and GDP (r^2=0.309, P=0.0004) and GSR and the number of ophthalmologists (r^2=0.476, P<0.0001).
Conclusion There is a paucity of data on rates of glaucoma surgery, particularly from developing countries. The new metric GSR may be useful for the allocation of healthcare resources, as well as for planning and monitoring public health interventions in glaucoma.

Keywords Glaucoma · Glaucoma surgical rate · Epidemiology · Filtering surgery

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Introduction

Glaucoma is the leading cause of irreversible blindness worldwide [1]. Although elevated intraocular pressure (IOP) is no longer considered to be a defining feature of the disease, it is still recognized as a major risk factor, and remains the only modifiable one [2]. The three treatment modalities by which IOP is lowered are medical therapy, laser intervention, and surgery. Despite the recognition of glaucoma as a public health problem by the World Health Organization (WHO) [3], its inclusion in subsequent 5-year plans of the VISION2020 Prevention of Blindness initiative has been prevented due to complexities in diagnosis [4] and treatment [5, 6]. Paucity of epidemiological data in glaucoma poses an additional challenge for the formulation of public health strategies.

The number of glaucoma surgeries performed worldwide is not known. A Medline search of published literature yielded only six countries with available data [7–12]. No published data were available from any developing country. This lack of data is significant for two reasons. First, the prevalence of glaucoma-related blindness is mostly at its highest in older populations who live in developing countries [3]. Second,

some investigators argue that, from a cost perspective, the adequate approach to tackle the glaucoma burden on the health systems of developing countries may be through surgery [5, 13].

Understanding trends and patterns in glaucoma management is of critical importance for clinicians, researchers, and policy-makers alike. In settings of low or reduced health care budgets, decision-makers increasingly determine the allocation of funds based on the availability of epidemiological data. Therefore, in the absence of global data on provision and uptake of glaucoma services, the needs of glaucoma patients are at risk of being further underestimated and unaddressed. Despite this need, no data on the global rates of glaucoma surgery are currently available. In this study, we expand the available knowledge on the worldwide numbers of glaucoma surgery (including cyclodestructive procedures) through a survey of national glaucoma and ophthalmological societies.

Methods

A list of 73 member national glaucoma societies was requested and provided by the secretariat of the World Glaucoma Association on January 6th, 2011. For countries without a national glaucoma society, the national ophthalmological society or national prevention of blindness committees ($n=35$) were identified through the database of the International Council of Ophthalmology (http://www.icoph.org/advancing_leadership/ophthalmologic_societies.html; last accessed June 4, 2011). For all other countries, non-governmental organizations (NGOs) and leading ophthalmologists were identified through conference participation lists and the authors' personal database. All contacts were contacted by email. Three attempts were made in each case. If addressees failed to respond, the particular country was recorded as "no response". When members' email addresses were expired or incorrect, they were contacted by mail ($n=4$). In the survey, we sought to obtain the total number of glaucoma surgeries between 2006 and 2010, stratified by type of glaucoma surgery [trabeculectomy, non-penetrating glaucoma surgery; combined filtering and cataract surgery; glaucoma drainage device (GDD)/tubes/valves; cyclodestructive procedures; and others (including more recent surgical procedures)]. Three levels of evidence were assigned. A level I rating was assigned to published epidemiological literature or data from central government and/or insurance registries. A level II rating was assigned to estimates provided by national professional societies based on a member survey, and a level III classification was applied to estimates provided by key ophthalmology leaders based on data emanating from individual institutions.

Population size and structure are based on the 'World Population Prospects: the 2008 Revision' from the United Nations Population Division [14]. Data on per capita health expenditure were obtained from the World Bank (World Bank, World Development Indicators. www.worldbank.org. Accessed on April 11, 2011). Data on per capita Gross Domestic Product (GDP) were obtained from the International Monetary Fund (IMF) (World Economic Outlook Database-April 2011, International Monetary Fund. www.imf.org. Accessed on April 11, 2011). For ease of comparison with other global epidemiological surveys, countries were grouped according to WHO regions: African region (AFR), region of the Americas (AMR), Eastern Mediterranean region (EMR), European region (EUR), South-east Asian region (SEAR), and Western Pacific region (WPR) [15].

For ease of comparison, we developed a new metric, the glaucoma surgical rate (GSR). GSR was defined as the annual number of total glaucoma surgeries performed per million population. Linear regression analysis was performed to evaluate the correlation between GSR to the number of population per ophthalmologist, GDP per capita (USD), and total health expenditure per capita (USD). For this analysis, both the dependent (GSR) and the predictor variable were log-transformed to correct for skewed data. Statistical analyses were performed using Stata 10.0 (StataCorp, College Station, TX, USA).

Results

In total, 73 national glaucoma societies and 35 national ophthalmological societies were contacted. For 11 other countries without any official professional organization, six NGOs and 37 leading ophthalmologists were contacted. The response rate was 71.2 % for national glaucoma societies, 60.0 % for national ophthalmological societies and national prevention of blindness committees, 100 % for NGOs, and 84 % for individually approached ophthalmologists. Data were obtained from 38 countries in five continents covering all six WHO regions, with a total population of 1.723 billion.

Table 1 shows the source and year of data as well as the estimated numbers of glaucoma surgery performed in each country. There was a wide variation in glaucoma surgical rates both within and between regions (Fig. 1). The region with the most data (18 countries) as well as the highest GSR was the European region, where the GSR ranged from 500.0 (Germany) to 85.2 (Netherlands). In the region of the Americas (eight countries), GSR ranged from 274.3 (USA) to 31.5 (Paraguay). In the Eastern Mediterranean region (six countries), Iran had the highest GSR (68.6) and Sudan the lowest (30.0). In the Western Pacific region (three countries), GSR ranged from 234.0 (Singapore) to 122.6 (South Korea). Data were available from two countries in the African region (Ghana, GSR 7.0 and Ivory Coast, GSR 2.9), and only one

Table 1 Sources of information for data on glaucoma surgical rates, by World Health Organization region

WHO region	Country	Source of data	Evidence level	Year	Number of glaucoma surgeries	GSR (sx/mill/year)
AFR	Ghana	MoH/NPBC	II	2010	167	7.0
	Ivory Coast	NPBC	III	2010	60	2.9
AMR	Bolivia	Glaucoma society	II	2010	286	29.0
	Brazil	Ophthalmologists	III	2010	3,286	16.9
	Canada	Published literature [11, 16]	I	2004	5,870	174.0
	Chile	Glaucoma society	II	2010	1,750	103.0
	Colombia	Glaucoma society	II	2010	2,900	63.5
	Paraguay	Glaucoma society	II	2010	200	31.5
	Puerto Rico	Glaucoma society	II	2010	171	43.1
	USA	Published literature [7]	I	2006	84,220	274.3
EMR	Iran	Ophthalmologists	III	2010	4,926	68.6
	Kuwait	Ophthalmologists	III	2010	150	53.7
	Oman	MoH	I	2010	102	35.9
	Pakistan	Glaucoma society	II	2010	10,000	58.9
	Sudan	Glaucoma society	II	2010	1,268	30.0
	Tunisia	NPBC	II	2010	500	47.9
EUR	Azerbaijan	Glaucoma society	II	2010	994	113.2
	Belgium	Insurance database	I	2010	1,556	144.2
	France	Published literature [9]	I	2000	22,890	365.6
	Georgia	Glaucoma society	II	2010	955	97.2
	Germany	Glaucoma society	II	2009	37,500	500.0
	Israel	Glaucoma society	II	2010	1,299	148.9
	Netherlands	Published literature [10]	I	2003	1,408	85.2
	Norway	Glaucoma society	II	2010	739	153.1
	Latvia	Glaucoma society	II	2010	563	250.0
	Lithuania	Glaucoma society	II	2010	1,095	365.0
	Poland	Glaucoma society	II	2010	6,500	170.4
	Portugal	Glaucoma society	I	2010	1,124	105.7
	Romania	Glaucoma society	II	2010	3,500	162.9
	Russia	Glaucoma society	II	2010	40,000	282.2
	Serbia	Glaucoma society	II	2010	676	92.4
	Slovenia	Glaucoma society	II	2010	210	105.0
	UK	Published literature [12, 17]	I	2004	7,191	132.4
	Ukraine	MoH	II	2010	13,700	297.8
SEAR	Bangladesh	Glaucoma society	II	2010	12,492	77.0
WPR	Australia	Published literature [8]	I	2003	4,010	183.3
	Singapore	Ophthalmologists	III	2010	1,167	234.0
	South Korea	Insurance database	I	2010	5,974	122.6

AFR African region, *AMR* region of the Americas, *EMR* Eastern Mediterranean region, *EUR* European region, *Ophthalmologists* Leading ophthalmologists, *MoH* Ministry of Health, *NPBC* National Prevention of Blindness Committee, *SEAR* South-East Asian region, *Sx* surgeries, *WPR* Western Pacific region

country in the south-east Asian region (Bangladesh, GSR 77.0).

Data from 21 countries provided a breakdown by type of surgery. Trabeculectomy was the most frequently performed glaucoma surgery in all 21 countries, accounting for an average 77.7 % of all glaucoma surgeries (range: Ivory Coast, 100 % to South Korea, 45.7 %). Six countries provided data on combined filtering/cataract extraction-surgery. In these, combined surgeries accounted for an average 9.7 % of all surgeries (range: Ghana, Latvia, Sudan, Tunisia, 0 % to Singapore, 47.0 %) In eight countries, in which data on non-penetrating glaucoma surgery (NPGS) were available, NPGS

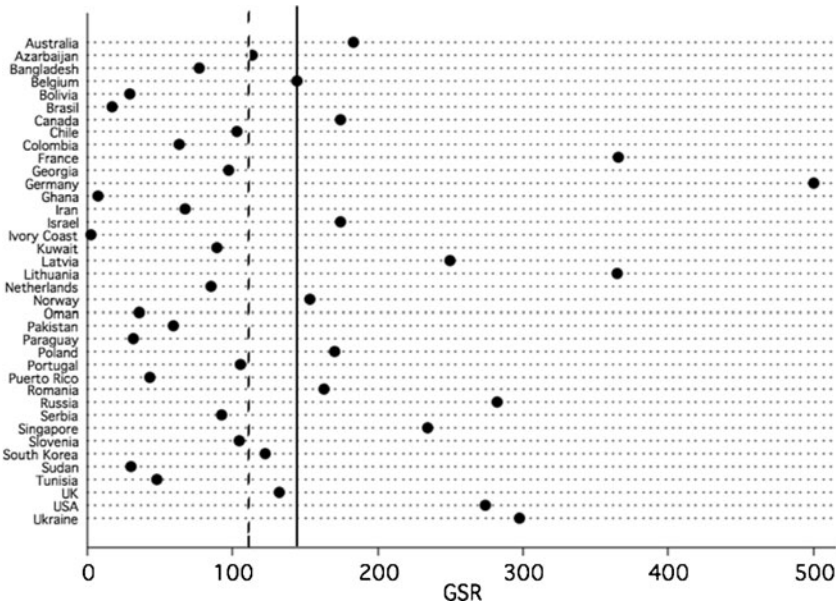

Fig. 1 Overview of glaucoma surgical rates (GSR) by country. *Vertical lines* indicate mean (*continuous line*) and median GSR (*interrupted line*)

constituted on average 6.6 % (range: Ghana, 0 % to Georgia, 20.0 %) of all glaucoma surgeries. Use of GDDs/tubes/valves accounted for an average of 8.9 % of all glaucoma surgeries in the 19 countries that had data on their use (range: Ivory Coast, Lithuania, 0 % to Puerto Rico, 36.3 %). Fifteen countries provided data on cyclodestructive procedures. These procedures constituted 7.8 % of all glaucoma surgeries (range: Bolivia, Chile, Ivory Coast, Ghana, Latvia, Puerto Rico, Tunisia, 0 % to Lithuania 21.9 %).

Using population data, we calculated the number of population per ophthalmologist. The mean number of people per ophthalmologist was 64,452 (median, 25,303,7; interquartile range, 27,316.8), with a minimum of 8,571 (Lithuania) and a maximum of 496,609 (Ghana) people per ophthalmologist. When GSR was plotted against the number of population per ophthalmologist based on the log-transformed model, a strong negative correlation (r^2=0.476, P<0.0001) was found (Fig. 2). After excluding the four countries (Ghana, Ivory Coast, Sudan, and Bangladesh) with a population/ophthalmologist ratio above 100,000, this correlation became weaker (r^2=0.208, P=0.010). There was also a positive correlation between per capita GDP and GSR (r^2=0.309, P=0.0004) after log-transformation (Fig. 3). A positive correlation was also found between total per capita health care expenditure and GSR (r^2=0.418, P<0.0001) after log-transformation (Fig. 4).

Discussion

The current study estimates global numbers of glaucoma surgery. Despite dedicated efforts from the study investigators and the contacted national glaucoma and ophthalmological societies, data were only available from 38 countries, with only six of them accessible to the scientific community via Medline.

A series of epidemiological studies and landmark glaucoma trials conducted in the past decade have led to better understanding of the global burden of glaucoma [3] and its treatment [18]. While the former enable a worldwide

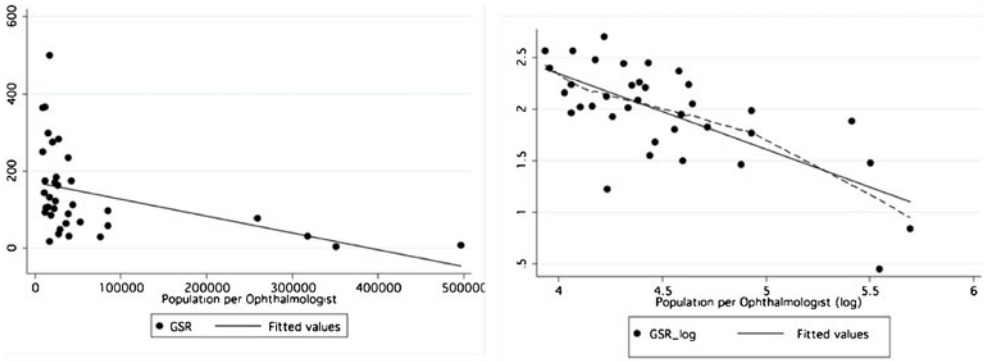

Fig. 2 **a**,**b** Scatterplot showing correlation of glaucoma surgical rates and number of population per ophthalmologist in absolute numbers (**a**, *left*) and after log transformation of both variables (**b**, *right*). *Lines* represent linear correlation (*continuous line*) and LOWESS smoothing (**b**, *interrupted line*)

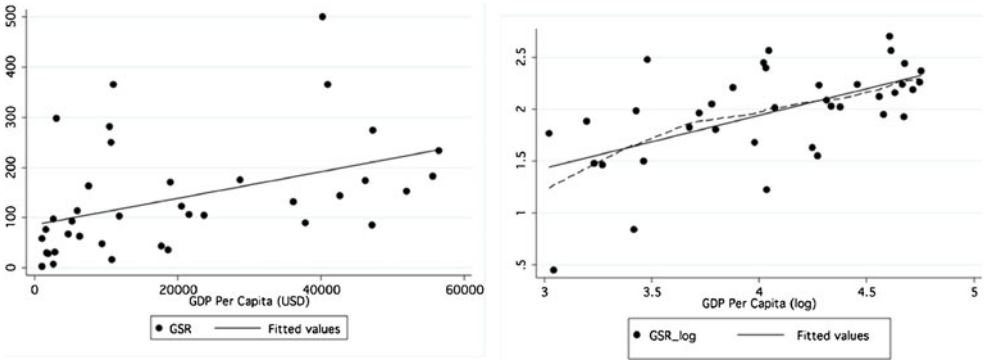

Fig. 3 **a**,**b** Scatterplot showing correlation of glaucoma surgical rates and per capita gross domestic product (2009, US$) in absolute numbers (**a**, *left*) and after log transformation of both variables (**b**, *right*). *Lines* represent linear correlation (*continuous line*) and LOWESS smoothing (**b**, *interrupted line*)

cartography of the prevalence of glaucoma, the latter provide evidence that IOP-lowering reduces the risk for the onset and progression of glaucoma. However, little is known about the numbers of glaucoma surgery performed worldwide, with the exception of a few developed countries.

There may have been a decline of surgical rates starting in the mid-nineties with the introduction of two new classes of topical glaucoma medications and new combination eye drops. In France, Baudouin et al. [9] found a decrease of 47 % in the number of glaucoma surgical procedures between 1997 and 2000. In the same period, the number of medically treated glaucoma cases increased from 410,000 to 734,000. Similarly, in the Netherlands, a 45 % decline of glaucoma surgery was registered in the same period. In Australia, Walland [8] found a decrease of 57.6 % in trabeculectomy rates between 1994 and 2003, and a decrease of 61.7 % from the peak rate in 1996. Although our survey had requested glaucoma surgical data from the preceding 5 years, only three countries were able to provide these numbers. In Belgium, between 1995 and 2010, the decrease in single procedure glaucoma surgeries (from 1,961 to 1,480 interventions) was overshadowed by a dramatic fall in combined glaucoma/cataract procedures (from 1,243 to 76), signifying a possible change in that country's practice patterns. In contrast, we found that in Bolivia the number of glaucoma surgeries increased from 147 in 2006 to 286 in 2010.

Despite limited country-specific data on types of glaucoma surgery, some conclusions can be drawn from our survey. Trabeculectomy constituted the overwhelming majority of glaucoma surgeries, with little uptake of NPGS, where data were available. Despite its reported better safety profile, the equivalence of NPGS to trabeculectomy in terms of efficacy remains controversial [19]. In addition to the long learning curve related to surgical skills and knowledge of the anatomy, the wide use of NPGS is still hindered by the increased cost related to the need for intraoperative use of space-maintainers [20, 21] and postoperative use of laser goniopuncture [22].

With the introduction of a new metric, GSR, as the number of glaucoma operations performed annually per million population, we seek to emulate the example of the cataract surgery rate (CSR), introduced in the 1990s [23]. The CSR enabled easy comparisons between countries and provided public health initiatives with an easy-to-measure success criterion [24]. Glaucoma is a chronic disease and glaucoma surgery, unlike cataract surgery, is frequently not sufficient as a single intervention. Consequently, it is not known what a sufficient and sustainable GSR is and it is possible that an "ideal" standard GSR does not exist. Campbell et al. [16], using Canadian provincial insurance databases, estimated the number of glaucoma surgeries per 1,000 patients with glaucoma to be 28. Using Canada with its widely accessible public health care service as an example of an ideal situation, 2.8 surgeries per 1,000 glaucoma patients per year could be used as a target. Using data from a population-based prevalence study [25], we have estimated the number of people above the age of 30 with glaucoma to be 614,228 in Ghana and 523,329 in the Ivory

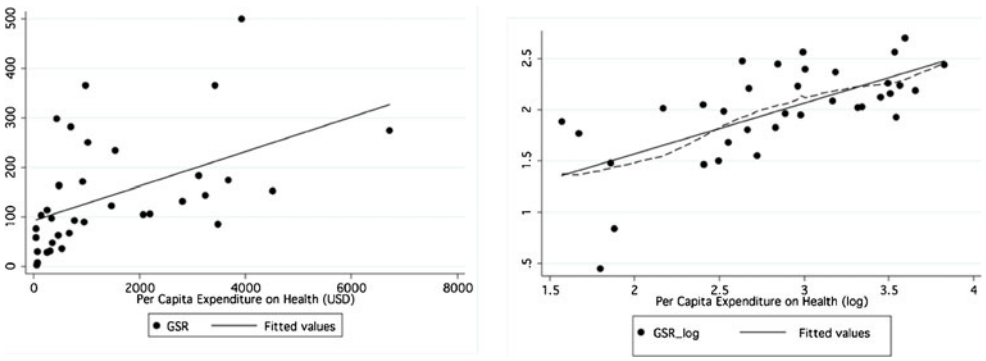

Fig. 4 **a**,**b** Scatterplot showing correlation of glaucoma surgical rates and per capita expenditure on health (2009, US$) in absolute numbers (**a**, *left*) and after log transformation of both variables (**b**, *right*). *Lines* represent linear correlation (*continuous line*) and LOWESS smoothing (**b**, *interrupted line*)

Coast in the year 2010 (unpublished data). These data were then used to project the target number of glaucoma surgeries as a function of the estimated 2010 population with glaucoma. Assuming a similar health care scenario as in Canada, 1,719.8 and 1,465.3 annual glaucoma surgeries would be necessary in Ghana and Ivory Coast respectively. This would correspond to a target GSR of 72.1 for Ghana and 69.5 for Ivory Coast, respectively, or a 10- (Ghana) and 24-fold (Ivory Coast) increase of the current GSR. This target GSR is, of course, a gross simplification, given very different socio-economic backgrounds as well as disease profiles between these West African countries and Canada. Furthermore, previous regional studies of glaucoma surgical rates have evaluated trends, since rates are dynamic and affected by a variety of influences.

The present study provides the first global estimates of the rates of glaucoma surgery. As such, it is subject to numerous assumptions and limitations. The first is a scarcity of data. Only 38 countries could provide data on glaucoma surgery, with only 33 of those emanating from a survey or a central database. These numbers compare well with initial estimates of the global burden of blindness (based on 17 countries) [26] and prevalence of glaucoma (based on 19 countries) [27]. Subsequent updates of these could rely on more data [28, 29]. It should be noted that data from India and China are absent. The authors are aware of efforts to gather data in these two countries that started as a consequence of this survey.

The issue of the reliability of data is another concern. These comparisons are limited by our inability to verify the provenance and accuracy of the obtained data. Estimates based on data provided by leading ophthalmologists (level III evidence) are particularly subject to bias. The dissociation of public–private health care provision is a further limiting factor in data collection. Countries with a strong centralized public health system have the best access to data. Other countries have mixed public–private health systems, which introduces uncertainties in the data. In the US, for example, data were only available from Medicare, which covers persons over the age 65 enrolled in Medicare fee for service, excluding younger patients, some privately insured patients, and patients receiving care from the US Veteran's Administration health care system. Finally, the new metric itself is limited by the use of the total population as the denominator. Using the population with glaucoma would have provided a more targeted metric. However, due to lack of data on glaucoma prevalence in many populations, this approach would have introduced an additional level of uncertainty into the metric.

Despite these limitations, our results provide a useful overview of the global rates of glaucoma surgery. We show that the availability of reliable and global data on the rates of glaucoma surgery is an unmet need. Results form the current study should raise awareness on the part of all stakeholders in the field of glaucoma that the scarcity of data should be addressed. The World Glaucoma Association and other supranational bodies are best placed to coordinate data collection on glaucoma surgical rates and provide technical expertise whenever requested. These data would be a key input that affects decision-making about how to allocate increasingly scarce health care resources. They could further encourage professional groups and the ophthalmic industry to make glaucoma surgery affordable for underprivileged populations.

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Contributions of authors

Design of the study (KM, RNW); conduct of the study (KM); statistical expertise (KM, FAM); writing the article (KM); critical revision of the article and final approval (KM, FAM, RNW); provision of materials, patients, or resources (KM, RNW).